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Pot Tests Indicate Fertilizers Can Improve Soils From Black Mesa In Western Colorado

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Greenhouse tests of the nutritive status of soils from Black Mesa in western Colorado indicate that production of herbage can be increased by use of fertilizers. A combination of 100 pounds of nitrogen and 200 pounds of phosphorus per acre increased yields about 30 percent under greenhouse conditions. Moravian barley produced maximum number of tillers (an indication of rate of plant enlargement) when 200 pounds per acre of potassium was added to the above combination. Results should be tested under field conditions.

On Black Mesa there are obvious differences in kind and amount of plant cover on what appear to be different, but yet related, sites. One site is on an old burn that occurred about 1880 in a spruce-fir forest. Here spruce reproduction is negligible and the herbaceous vegetation is still sparse. On other sites, generally with shallow and rocky soils, hairy goldaster (Chrysopsis villosa (Pursh) Nutt.) is prominent and there are very few plants of other species. In contrast, the majority of the area supports a lush growth of herbaceous vegetation with Idaho fescue (Festuca idahoensis Elmer) predominating.

It was suspected that fertility levels of the soils on the three sites might be partly responsible for the differences in herbaceous cover. For this reason, a study was designed to determine the effect

of nitrogen (N), phosphorus (P), potassium (K), and micronutrients (M) on the productivity of the soils. Surface soils from the three sites described were used in pot tests under greenhouse conditions.

Methods

Approximately 100 pounds of the surface 6 inches of soil were collected from two randomly located areas within each of the three sites. The soil materials from each area within a site were composited in the field to form one sample per site. The soils were screened through 1/4-inch mesh to remove rocks and other extraneous material. The fertilizer treatments were as follows:

1. Ammonium nitrate equivalent to 100 pounds per acre elemental N.
2. Mono-basic calcium phosphate equivalent to 200 pounds per acre P_2O_5 .
3. Potassium sulfate equivalent to 200 pounds per acre K_2O .

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4. Micronutrients in a form approximating the stock solution described by Bonner and Galston² were added as follows:

	<u>Pounds per acre</u>
Boron (H_3BO_3)	11.2
Manganese ($\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$)	24.7
Zinc ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$)	2.5
Copper ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)	2.8
Molybdenum ($\text{H}_2\text{MoO}_4 \cdot 4\text{H}_2\text{O}$)	1.8
Magnesium (MgSO_4)	2.2
Iron ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$)	0.4
Calcium ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)	5.0
Sulfur (From above)	11.4

Greenhouse Procedures

The soils were evaluated in 6-inch plastic pots lined with plastic bags to prevent contamination. Each pot contained 1,600 grams of the screened and thoroughly mixed soil.

The required amount of each fertilizer for each treatment was dissolved in distilled water and added to each pot. Sufficient distilled water was applied at the beginning to assure adequate wetting of all soil in the pots. The soil was subsequently kept moist, but not wet. Photoperiod was 14 hours of combined artificial and natural daylight. Greenhouse temperature was about 70° F. during the daytime and 40° F. at night; humidity was not controlled.

Moravian barley (*Hordeum vulgare* L.) was used as a tester species; 10 seeds were planted in each pot. When germination was complete, each pot was thinned to the five most vigorous seedlings. These were allowed to grow until they reached the seed-in-boot stage on the control treatment. At that time the number of tillers was counted and herbage from all pots was harvested.

²Bonner, J., and Galston, A. W. *Principles of plant physiology*. 499 pp. San Francisco: W. H. Freeman and Co. 1952.

Results

Treatments were evaluated on the basis of germination, number of tillers, and herbage weight (table 1). Data were analyzed by methods of variance, and a probability level of 0.05 was accepted for determining the significance of difference between treatments. Calculation of main effects and interactions (shown in lower case, table 2) followed the procedure outlined by Cochran and Cox.³

Germination

Almost all seeds germinated in all pots, which indicates fertilizers had no effect on germination. For this reason these data were not analyzed statistically. Such high rates of germination (over 97 percent) probably could not be expected under field conditions, and certainly not with most native species. In only one treatment was there any indication of possible effect. When the combination of NPM was applied, there appeared to be a consistent depression of germination down to 93 percent on soils from all sites.

Herbage Yield

As suspected, the productivity of the three soils in this study was different (table 1). Average yields, without and with fertilizer, in grams per pot, green weight, were:

	<u>Without</u>	<u>With</u>
Soil type:		
Burn	27.7	32.2
Goldaster	30.1	33.9
Fescue	41.4	44.3

Maximum yields were obtained from the NPK treatment. Potassium, however, did not contribute significantly to the increase. Therefore, the NP combination could be expected to produce as much herbage as the NPK combination.

Although the NPK fertilizer (or the NP) did increase the production from all soils, it did not greatly change the relationship between them. This

³Cochran, W. G., and Cox, G. M. *Experimental designs*. Ed. 2, 611 pp. New York: John Wiley and Sons, Inc. 1957.

Table 1.--Effect of fertilizers on herbage yield of Moravian barley (grams per pot, green weight) and number of tillers on soils from burn, hairy goldaster, and fescue sites

Treatment	Herbage yield				Tillers			
	Burn	Aster	Fescue	Average	Burn	Aster	Fescue	Average
	- - - Grams per pot - - -				- - - Number - - -			
Control	27.7	30.1	41.4	33.1	0	0	5.0	1.7
N (100 lb/acre)	34.1	34.9	45.3	38.1	1.7	0	7.7	3.1
P (200 lb/acre)	28.3	30.2	43.1	33.9	.7	.3	6.3	2.4
NP	35.2	39.1	46.2	40.2	1.0	3.0	9.0	4.3
K (200 lb/acre)	28.2	30.2	41.0	33.1	0	0	5.7	1.9
NK	36.4	36.1	43.9	38.8	4.0	.7	6.0	3.6
PK	28.3	31.1	44.1	34.5	1.0	1.3	9.0	3.8
NPK	37.1	38.3	50.0	41.8	5.7	4.0	10.0	6.6
Micronutrients (M)	27.8	29.8	41.4	33.0	0	0	3.7	1.2
NM	35.7	35.7	45.1	38.8	2.3	1.3	6.3	3.3
PM	28.5	31.8	43.0	34.4	.3	0	10.0	3.4
NPM	36.5	37.6	48.1	40.7	3.3	5.0	7.3	5.2
KM	28.0	29.5	39.9	32.5	0	0	6.3	2.1
NKM	35.2	36.0	43.1	38.1	2.3	1.0	8.0	3.8
PKM	28.1	30.9	44.0	34.3	0	1.7	6.3	2.7
NPKM	35.4	37.3	47.3	40.0	4.7	3.7	9.3	5.9

Table 2.--Analyses for single degree of freedom, main effect and interaction comparisons¹ of herbage yield and number of tillers on Moravian barley

Source	Herbage yield			Number of tillers		
	Degrees of freedom	Mean square	Main and interaction means	Degrees of freedom	Mean square	Main and interaction means
Total	143			143		
A (soils)	2	2120.03**		2	524.44**	
B (fertilizers)	15	95.21**		15	20.32**	
n	1		2.98**			1.03**
p	1		.89**			.85**
np	1		.20*			.17
k	1		.07			.34**
nk	1		.06			.13
pk	1		.13			.09
npk	1		0			.16
m	1		-.10			.02
nm	1		-.05			.06
pm	1		0			-.01
npm	1		-.15			-.02
km	1		-.33**			-.19
nkm	1		-.16			-.01
pkm	1		-.07			-.27**
npkm	1		-.05			.07
A x B (soils x fertilizers)	30	5.62**		30	4.28**	
Error	96	1.02		96	1.39	

¹Calculations of main effects and interactions, shown in lower case, follow procedure outlined by Cochran and Cox (see text, footnote 3).

* Indicates significance at the 5 percent level.

**Indicates significance at the 1 percent level.

might indicate that higher rates of application, especially on the burn and goldaster soil, would be more productive, or it might indicate that some other factor in the soil is also deficient. It was observed during the course of the study that both the burn and goldaster soils dried more quickly than the fescue soil. This could have been related to soil texture or organic matter, but these factors were not measured.

The effect of fertilizers and the interaction of soils and fertilizers were both highly significant. In spite of this interaction, there were some consistencies in the results. On all soils, production was higher with amendments containing N. On two soils (burn and fescue) the amendment NPK produced maximum yields, and on the goldaster soils NPK was slightly below NP, but not different from it. The amendment NPM followed the same trend as NPK, but as with potassium, the micronutrients did not contribute significantly to the increased production.

Some of the main effects of fertilizers were important (table 2). Nitrogen (n) strongly increased production on all soils. Phosphorus (p) had an important main effect. Nitrogen and phosphorus (np) interaction was positive and significant at + 0.20 gram/pot. Neither potassium (k) nor the micronutrient (m) solution affected yields. The interaction (km) was significant ($P < .01$) due to the depressing effect of m. It is of interest that the signs of all treatment interactions involving the micronutrients were negative, indicating a depressing effect on yield. Micronutrients also depressed yields in a similar study on alpine soils from Wyoming.⁴

Number of Tillers

Without fertilizers, only soils from the fescue site produced tillers—an average of five per pot (table 1).

Nitrogen (N) and phosphorus (P) as separate applications increased the number of tillers, and in combination were superior to either amendment alone. Potassium (K) alone was not effective. Nitrogen (N) alone had no effect on the goldaster soils. Phosphorus (P) had some effect on all soils, and

potassium (K) had only a slight effect on the fescue soils.

Combinations of NP, NK, and PK were more effective than the individual amendments alone, and tillering was maximum when all three elements were combined. Some other combinations, NPM and NPKM, were almost as good as the NPK, but a depressing effect (not significant, however) was indicated, probably due to the micronutrients.

The analysis of the number of tillers produced showed significant differences between soils, significant effects of fertilizers, and a strong interaction between soils and fertilizers ($p < .01$, table 2). The main effects of n, p, and k were all significant ($p < .01$). However, none of the interactions involving these three amendments was significant, which indicates that the effects were independent of each other. The pkm combination was significant ($p < .01$), but the sign was negative, again indicating a depressing effect. In this case some interaction between k and m and between p and m appears to be responsible.

Summary

Results from greenhouse studies on the effect of fertilizers cannot be expected to apply directly to field trials. They do, however, direct attention to those fertilizers which appear to be most promising for further tests under actual field conditions. In this case, the results indicate that substantial increases in herbage yields might be expected when nitrogen and phosphorus are applied in combination. The addition of potassium might have a tendency to increase the rate of enlargement of individual plants, thus increasing the amount of ground cover. Its addition to a combination of nitrogen and phosphorus might increase costs somewhat, but certainly should not decrease herbage yields.

The failure of the soils from the three sites to reach the same level of productivity might mean that tests of different rates of application would be in order. It is entirely possible, however, that other inherent soil factors, such as those connected with the moisture regime, may be involved. Hints of this effect were observed in the greenhouse in the differential rates of drying among the three soils.

Nevertheless, it appears that fertilization of soils on Black Mesa will be effective in increasing herbage yields. Field testing and cost-benefit studies are needed, however, as the first step toward a management program in this field.

⁴Johnson, W. M., and Smith, Dixie R. *Pot tests of productivity and nutritive status of three alpine soils in Wyoming.* U. S. Forest Serv. Res. Note RM-75, 7 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.